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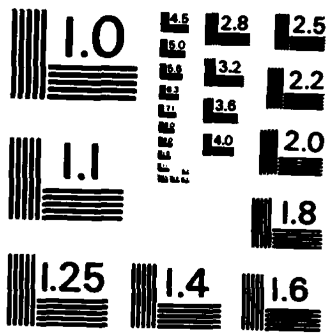

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The investigators are in the final stages of developing a "toolkit" of symbol manipulation codes for variational grid generation. They will present an invited paper on this work at an AIAA Aerospace Sciences Meeting. They have also discovered an unexpected folding of the grid for a design case using a popular grid generation code. A paper analyzing the problem was presented at the AIAA Computational Fluid Dynamics Meeting in July. The analysis has suggested practical values of relative weighting parameters for use in variational grid generation techniques. A paper has been submitted to the journal Applied Mathematics and Computation. Additional keywords: Grids (coordinates); adaptive systems

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SUBJECT: Research Progress and Forecast Report for Contract F49620-84-C-0079, "Adaptive Grid Generation Using Elliptic Generating Equations with Precise Coordinate Controls"

Dear Captain Thomas and Dr. Wilson:

This letter constitutes the required report on the subject contract. Generally, progress continues to be excellent. The topical headings below follow those in our proposal.

1. Use of Symbolic Manipulation.

The use of computer Symbolic Manipulation to perform the theoretical manipulations for the several variational formulations and to produce the Fortran subroutines for numerical work continues to be productive. We are in the final stages of developing a "toolkit" of Symbol Manipulation codes for variational grid generation, and we will be presenting an invited paper on this work at an Artificial Intelligence session at the AIAA Aerospace Sciences Meeting this January in Reno. (This work is also partially sponsored by ARO.)

2. Variational Formulation and Reference Grid Definition.

A summary paper on variational grid generation principles, with several variational formulations, has been prepared and submitted for publication.

3. Variational Formulation in Logical Space rather than Physical Space.

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This fundamental departure from the historically popular approach, as described previously. We have now re-interpreted the "smoothness" operator in logical space, and find that it really is more meaningful to view it as a constant segment length condition. This interpretation clearly indicates why folding occurs with this formulation and the more common smoothness in physical space, and further suggests a cure for the folding which involves the judicious use of our "reference grid" approach. The key is that the segment length specifiction should vary with the region boundaries,in an easily prescribed way. We are expecting this approach to significantly improve the grids obtained with logical space "smoothing" variational principles; testing and validating of this concept and the other varitional formulations will occur in the next reporting period.

Our work on the unexpected folding of the Winslow (homogeneous Thompson-Thames-Mastin) method (which supposedly always gives a non-folded grid generation in 2D because of the maximum principle of the homogeneous equations) was received with considerable interest at the AIAA Computational Fluid Dynamics Meeting in July. The analysis was based on the closed form solutions for minimal grid resolutions, i.e. a 3x3 grid. We have applied this approach more extensively now, to analyze not only the folding of the Winslow method, but also the folding of variationally produced grid generation equations. The analysis has suggested practical values of relative weighting parameters for the various variational equations, and numerical experimentation in finer grids indicates that the values so obtained are indeed practical. A summary paper on these results has been submitted for publication. This work has also shown that variational volume control alone does in fact produce a unique system of equations in the minimal grid resolution, contrary to the theorem cited by Brackbill and Saltzman. We are working on a correct interpretation of these conflicting results.

4. Solution Procedure Minimizing Storage Requirements and/or Arithmetic Operations

This strategy involves a solution formulation in which the matrix equation is expressed as a variables-separable elliptic operator, with a nonhomogeneous term which includes all the nonlinearities and non-separable coefficients. The performance has been excellent, provided that the grid generation parameters are such as to generate a good grid. We have incorporated this formulation into a single equation multigrid (FAS) algorithm, with improved convergence rates for fine mesh calculations.

This work led to a consideration of sub-grid and super-grid coefficient generation for "black box" multigrid codes which has been fruitful. A concept evolved for generation of sub-grid coefficients given only the discretization on the fine grid, without reference to or knowledge of the underlying continuum equations. The concept was further extended in the opposite direction, allowing primitive coefficient generation on something less than the finest grid of interest, followed by an economical "prolongation" to the finer grids. The concept is most applicable to systems wherein the cost per node point of generating the coefficients is high, precisely the case with the variational formulations. It is expected to result in a savings by a factor of 5 (limit 8) for 3D grid generation. The work was presented at the Second Copper Mountain Multigrid Conference in March, and interest was high from attendees including A. Brandt, J. Dendy, and U. Trottenberg.

5. Collaborative Work with Dr. Eiseman.

Collaboration with Dr. Eiseman continues to be quite helpful. We have enjoyed discussions with him prior to and during the AIAA CFD Meeting in Cincinnati this July. Discussions have covered a wide range of topics related to grid generation; particularly noteworthy are the topics of the uniqueness of the varitional volume control equations (see #3 above), surface and curvature variational formulations, computing and graphics needs and capabilities, behavioural errors such as grid folding and jacobian positivity, evaluation of competing grid generation concepts, judging grid quality, and his own approach of iterative re-distribution of segment lengths. We will be making a trip to visit him at Columbia this spring, and will provide him with our codes and assistance in installing them at his facility.

6. Interest from Air Force Weapons Laboratory.

We have not heard any more from AFWL personnel here in Albuquerque who had previously expressed interest in contracting to create a PC version of some of our grid generation methods. We will be meeting in mid-August to discuss future funding for our continued development of the ELF electrode design codes, and we will request funds to incorporate our new variational methods and multigrid techniques (developed under the subject contract) into the 2D and 3D ELF codes.

7. Publications Partially Supported Under the Present Contract.

7.1 "Symbolic Manipulation and Computational Fluid Dynamics", Stanly Steinberg and Patrick J. Roache, Jour. Computational Physics, Vol. 57, No. 2, Jan. 1985, pp. 251-284.

7.2 "Application of a Single-Equation MG-FAS Solver to Elliptic Grid Generation Equations (Sub-grid and Super-grid Coefficient Generation)', Patrick J. Roache and Stanly Steinberg, Proc. Second Copper Mountain Conference on Multigrid Methods, 1-3 April 1985, Copper Mountain, Colorado. To appear.

7.3 "Variational Grid Generation", Stanly Steinberg and Patrick J. Roache, submitted for publication to Numerical Methods for Partial Differential Equations.

7.4 "A Tool Kit of Symbolic Manipulation Programs for Varia tional Grid Generation", Stanly Steinberg and Patrick J. Roache, AIAA Aerospace Sciences Meeting, 6-9 Jan. 1986, Reno, Nevada. To appear.

7.5 "A New Approach to Grid Generation Using a Variational Formulation", Patrick J. Roache and Stanly Steinberg, AIAA -85-1527-CP, Proc. AIAA 7th Computational Fluid Dynamics Conference, 15-17 July 1985, Cincinnati, Ohio.

7.6. "On the Folding of Numerically Generated Grids", Jose Castillo, Stanly Steinberg and Patrick J. Roache, submitted to Applied Mathematics and Computation.

7.7 "Electric Field Calculations Using the ELF Codes", M. von Dadelszen, W.M. Moeny and Patrick J. Roache, Proc. IEEE Pulsed Power Conference, Crystal City, DC, 10-12 June 1985. To appear.

7.8 "The ELF Codes: Electrode Design for Lasers and Switches", Patrick J. Roache, Invited Paper, Proc. CTAC-85 Conference, Melbourne, Australia, 25-28 August 1985. To appear.

8. Presentations Partially Supported Under the Present Contract.

8.1 "Symbolic Manipulation and Computational Fluid Dynamics", Patrick J. Roache, Mechanical Engineering Seminar, University of California at Davis, 2 May 1985.

8.2 "Symbolic Manipulation and Computational Fluid Dynamics", Patrick J. Roache, Applied Mathematics Seminar, Sandia National Laboratories Livermore, Livermore, California, 7 May 1985.

8.3 "Variational Grid Generation", Stanly Steinberg, Applied Mathematics Seminar, Sandia National Laboratories Livermore, Livermore, California, 14 May 1985.

8.4 "A New Approach to Grid Generation Using a Variational Formulation", Patrick J. Roache and Stanly Steinberg, AIAA 7th Computational Fluid Dynamics Conference, 15-17 July 1985, Cincinnati, Ohio.

(future presentations)

8.5 "The ELF Codes: Electrode Design for Lasers and Switches", Keynote Lecture, Patrick J. Roache, Computational Techniques and Applications Conference, Royal Melbourne Institute of Technology, Melbourne, Australia, 25-28 August 1985.

8.6 "A Tool Kit of Symbolic Manipulation Programs for Variational Grid Generation", Invited Paper, Stanly Steinberg, AIAA Aerospace Sciences Meeting, 6-9 Jan. 1986, Reno, Nevada.

9. Design Optimization

In regard to my future work on design optimization utilizing the ELF codes, my visit to AFOSR on 18 July was most helpful. The pre-publication paper of Polak's provided by Dr. Mark Jacobs proved to be just what I need. I have contacted Polak and he has been receptive to investigating the use of his algorithms for the electrode design problem. We had scheduled a visit for me to Berkeley in August, but I will have to cancel because of the press of final report preparation on another contract, and my visit to Australia. I may not be able to visit him until October (due to jury duty in September) but I definitely will pursue this.

10. Computer System Purchase

Vernita Slater of AFOSR says that I may expect the computer money in late August. I very much appreciate your vote of confidence.

I did not receive the requested funding from ARO for the rest of the system I had described in my Request for Additional Equipment Purchase of 7 February 1985. The mathematics people at ARO were willing, but ARO policy prohibited it for legal reasons. ARO is willing to charge the contract for the increased operating costs if Ecodynamics would purchase the rest of the system, but this will cause great accounting difficulties, and we would likely run afoul of DCAA auditing regulations.

Further, the cost of the MicroVax II is not as attractive as I had been led to believe. The hardware costs are close to the estimates I had been given, but the software costs are outlandish. DEC wants $7K (after discount) for the VMS operating system and documentation, and another $7K for UNIX.

By contrast, the SUN microsystem (which Prof. Steinberg is now getting up at the university) is lower in cost for the hardware, and includes UNIX (Berkeley 4.2), Fortran 77, Pascal, "C", and Core Graphics Software for no extra cost. The discounted price for the SUN is only slightly over the $21.5K requested from AFOSR, and Ecodynamics can make up the difference. The present SUN based on the virtual memory 16/32 bit MC 68010 is faster than the MicroVax I, and the upgrade to the full 32 bit MC 68020 (available in November) is expected to be somewhat faster than the MicroVax II. Skye systems is bringing out their Warrior array processor, a 15 Megaflop device for $12K, including a 1024 FFT; their two primary target computers are the MicroVax II and the SUN. (I would seek additional funding, probably from AFWL, for the array processor.) I have also investigated (with consulting from Professional Computer Consultants of Albuquerque) two alternative systems, the AT&T UNIX 7300 and the IBM AT with the DSI-32 co-processor. Although both are cheaper than the SUN, the SUN appears to be preferable.

The only advantage left to the VAX is compatibility to the VAX world, which may not be worth the price. Also, the SUN compatibility with Steinberg's system would be an advantage. Note also that Prof. Polak at Berkeley has a SUN, Los Alamos Labs have adopted SUN as their standard workstation, and Dr. N. L. Rappagnani at AFWL uses a MC 68000 machine with Berkeley 4.2 UNIX for his grid generation work.

If Steinberg's experience is positive, I will probably be requesting a change in my previous Request For Additional Equipment Purchase from the MicroVax II to the SUN System 2/130.

Thank you both for your continued support.

Respectfully,

Patrick J. Roache

Dr. Patrick J. Roache
President and Principal Investigator

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